Space Communications Technology Link

A Quarterly Publication of the Space Communications Program
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Changing the way NASA and the Nation Communicate through Space.

Changes in NASA Lewis Research Center's Space Communications Program

Over the last two years, management of NASA's Space Communications has taken some new directions.

Mergers, acquisitions, phase-outs, buyouts, and downsizing—once solely the domain of the business world—have been affecting the structure and strategy of the Lewis Research Center Space Communications Program.

Our primary sponsor, Code X, the Office of Access to Space and Technology, was dissolved in October 1996 and the communications technology portion of the Lewis program was sent to Code SM, the Office of Advanced Technology and Mission Studies in the Space Science Enterprise. Meanwhile, the responsibility for demonstrating communication technology projects (such as the Advanced Communications Technology Satellite (ACTS) was transferred to the Space Operations Management Office (SOMO) under the Human Exploration and Development of Space Enterprise. SOMO, a relatively new organization located at the Johnson Space Center, is charged with consolidating and reducing the cost of NASA's space operations.

Additionally, Lewis has been impacted by the agencywide downsizing of the NASA Civil Servant and Contractor workforce and reduced budgets.

While these factors have effected the day to day development and insertion of communications technology, a number of new and exciting opportunities have come to Lewis. Overarching all of these factors is an emphasis on the Space Communications Program to support the agency needs. Clearer responsibilities for Space Science, Earth Science, and Human Exploration and Development of Space have been identified. In addition, new responsbilities for aeronautical applications have been secured. The Space Communications Program at Lewis now supports all four NASA Enterprises. Here is just a sample of some of the changes that are occurring within our organization.

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Spectrum Management
Down-sizing at HQ brought spectrum management responsibility for the Agency to Lewis. This role naturally puts us right at the heart of communications issues and keeps us focused on the future.

NASA Transition to Commercial Communications Assets
Lewis has been asked to support the Johnson Space Center in its role to transition NASA from using government designed and operated communication systems to commercially owned technologies and services. Lewis will provide both management and technical expertise to this important program. Stay tuned for news on this exciting program. A coming event: demonstrating new communication technology on the International Space Station to open new markets for operational services in the remote sensing industry!

Aerocomm
We have expanded our program to embrace satellite-based aeronautical communications for air traffic management and weather information networks, to save lives, money and time, while reducing the impact on our environment. Safety and air traffic are two important goals of the agency's aeronautics program.

New Leadership
The call for leadership and direction across the Space Communications Program was answered by seven newly appointed managers and supervisors. (see our new organization chart on the back of this newsletter). We are all working together to leverage our experience in technology, flight projects, and program management to craft a new strategy for success. This strategy will assure the continued success of the SCP.

A three-part mission has been established for the SCP which is serving as the foundation for this robust program (see insert).

We intend to accomplish our mission by advocating, developing, demonstrating and inserting enabling communications and network technology for high performance space communication systems—bringing the traditional strengths of the Lewis Space Communication Program and its people to bear on new technical challenges.

A New Look For Our Newsletter
It might seem like a trivial matter, but expanding the focus of our newsletter to encompass all the elements of our program is a necessary outgrowth of all this change. In addition to showcasing the accomplishments of ACTS, we will begin highlighting breakthroughs in communications technology and spotlighting events and activities supported by the Space Communications Program. Thanks to those of you who provided feedback to the survey in the Spring '98 issue of the ACTS Quarterly. This information has helped guide our new direction. Please continue to provide us your comments and watch for more changes in the future.

Using our knowledge, experience and strength from the past and our insight and plans for the future, the Lewis Space Communications Program is rising to new heights. Along with our Agency Colleagues and our Industry Partners, we are changing the way NASA and the Nation communicate through space….come grow with us!

For more information about the Space Communications Program at NASA Lewis Research Center, please contact:

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Space Communications Program Mission Statement

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- To support specific mission and operation needs of NASA and other federal agencies
- To enable NASA's utilization of commercial communications systems
- To enhance US Satellite industry capabilities

Silicon Germanium Expert, Dr. Bernard Meyerson, visits NASA Lewis

Jorge A. Quintana, Digital Communications Technology Branch, NASA Lewis Research Center

On December 10, 1997 Dr. Bernard Meyerson, an IBM Fellow, visited NASA Lewis Research Center to present his work on Silicon Germanium (SiGe), an emerging state-of-the-art technology that enables speeds in the GHz frequency range while consuming less power than regular Si components.

Dr. Meyerson is collaborating with Sierra Monolithics, a Small Disadvantage Business (SDB), in the development of a 10 Gbps/port Fast Packet Switch for next-generation satellite communications systems.

What is Silicon-Germanium?
Silicon-Germanium (SiGe) is a new 50 GHz technology from IBM that combines the integration and cost benefits of silicon with the speed of more esoteric and expensive technologies such as gallium-arsenide. Germanium introduced into the base layer of an otherwise all-silicon bipolar transistor creates significant improvements in operating frequency, current, noise, and power capabilities. At the same time, the key advantages of a state-of-the-art, 200 mm silicon BiCMOS process are maintained, including high integration level and economy of scale.

What are Some SiGe Applications?
Some SiGe application products include:

(a) 1.8 GHz and beyond wireless voice and data phone systems on a single chip.

(b) High-speed A/D and D/A converters for data acquisition, direct-to-baseband radio receivers, signal synthesis, and more.

(c) Low-cost, reliable Global Positioning Satellite (GPS) receivers.

(d) Other innovative high-frequency products as the market evolves.

Recently, IBM and Hughes have announced a multi-year agreement to create high-speed communications products based on a new type of silicon chip that is several hundred percent faster than current commercial offerings. New industries involving cellular, PCs, wireless local area networks, Direct-To-Home (DTH) satellite services and satellite-based communications are all dependent on ultra-low-cost and high-speed integrated circuit technology to reach a broad consumer market.

Why is NASA Interested in SiGe?
The Communications Technology Division of NASA Lewis Research Center is developing technology for next generation satellite systems that include both RF and high-speed digital components. For space qualified components, speed, power efficiency and low mass are critical. Vast improvements shown by this technology in these areas is essential for the development of future commercial satellite systems as well as future NASA missions to be integrated in the National and Global Information Infrastructure (NII/GII) initiative.

Biography of Dr. Bernard Meyerson
Dr. Bernard Meyerson received a PhD in physics from the City College of the City University of New York in 1981. His invention of the Ultra-High Vacuum Chemical Vapor Deposition (UHV/CVD) techniques along with his work in electronic materials has resulted in many awards including the 1993 ECS Electronics Division Award. Dr. Meyerson was appointed to the position of IBM Fellow by the chairman of the board in 1992. At present he is the Directior of Silicon Germanium Technology.

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Space Agencies Coordinate Use of Radio Frequency Bands

This article first appeared in the July 13, 1998 issue of the HQ Bulletin

NASA, the European Space Agency (ESA), and the National Space Development Agency of Japan (NASDA) met at the Lewis Research Center April 29-May 1 to coordinate the use of radio frequency spectrum bands common to their space programs. This is

Co-chairs of the Annual ESA/NASA/NASDA Frequency Coordination Meeting; Gerhard Block (ESA); David Struba (Office of Space Flight); and Fuda Mitushiko (NASDA) with participant James Hollansworth (LeRC).

the 23rd annual coordination meeting for NASA and ESA. NASDA has participated in the meeting over the past 10 years.

The primary intent of this annual coordination activity is to plan operations to avoid harmful radio frequency interference, which could compromise affected agencies' missions. In addition, attendees define new spectrum regions required for future missions and collaborate to develop a common strategy to secure access to the bands on a protected basis working within the international community's International Telecommunications Union.

Radio frequency spectrum bands are a limited national resource critical to the programs of these agencies. All satellite telecommunications systems supporting command, control, tracking, and data delivery require access and use of the spectrum to various degrees.

HTS Subsystems to Offer Reductions

Joseph Warner, Electron Design Technology Branch, NASA Lewis Research Center

On-going NASA cooperative agreement NAS3-517 with COMDEV, Dupont, and Lockheed-Martin has identified commercial communication's sub-systems that will have mass savings, power savings, and performance enhancements which have a positive value in terms of costs and benefits if the sub-systems are implemented in High Temperature Superconducting (HTS) and cryogenic technologies. For selected sub-systems on the spacecraft a weight savings of 50% or more, an enhancement of +2.5 db or more in G/T for a receiver, or a power savings of +100 watts can be realized. These numbers include the mass and power needed for the cryocooler. Though sterling cycle cryocoolers have been flown in space, primarily for sensors applications, there exists the perception, for the new flexure beaming pulse tube cryocooler, within the commercial communications world that they are heavy, inefficient and unreliable. The first two perceptions can be overcome through ground demonstrations.

As an example, pulse tube cryocoolers with cooling power of greater than 4 watts have been designed, built and tested under this agreement. Their efficiency is twice that of previous coolers and weighs only 3Kg with electronic controller when made to be space qualified. The third perception, according to senior industrial system analysts, must be overcome by a flight demonstration for a modern high-efficient cryocooler whose size, construction, and cooling power could be used in a communication sub-system. Flight tests will be sought within the next few years of a cryocooler and HTS microwave devices for a space communications link. The successful tests will influence satellite design and architecture by the mid-2000. These influences will keep the U.S. satellite industry second to none. For more information you may contact the author at:

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...Future Event

Satellite Communications and Expo Conference—SCEC 1998

TCP/IP over geo-satellites...dispelling the myth. NASA along with a team of industry partners reveal their results of HDR experiment 118x at the September SCEC show in Washington, D.C. For details about the show or for a free pass to the exhibition hall, e-mail us at: ***spacecom@lerc.nasa.gov***

Satellite Networks 1998 Workshop Report

The Satellite Networks: Architectures, and Technologies workshop, held in Cleveland on June 2-4, drew nearly 300 attendees and participants from industry, academia, and the government. The workshop, hosted by NASA Lewis' Space Communications Program, presented an opportunity for the communications community to collectively explore the impact of broadband data services and the convergence of satellite and terrestrial networks on the global information infrastructure.

The workshop was opened by NASA Lewis Center Director, Donald J. Campbell, who welcomed participants and congratulated them for being involved in one of the nations leading edge technology programs which will continue to advance and enhance global communications. Mr. Campbell affirmed NASA's support for the workshop and introduced NASA's Commercial Communications Program Manager, James Bagwell.

Mr. Bagwell presented the history and background of events that resulted in the formation of the Satellite Industry Task Force (SITF). Members of the task force and other key players of the NASA/Industry Program addressed the technical challenges facing commercial enterprises and NASA's response to these challenges. The presenters included:

- Samuel Venneri, Chief Technologist; NASA Headquarters
- Thomas Brackey, Executive Director of Technical Operations; Hughes Space & Communication
- Prakash Chitre, Vice President of Technology, COMSAT Laboratories
- Dr. Ramon DePaula, NASA Headquarters; Communications Program Executive Code SM
- Charlene Gilbert, SOMO Technology Manager, NASA Johnson Space Center

Technical sessions covering a wide range of topics offered the audience an opportunity to delve into specific areas of interest. Opening the technical program was Dr. Kul Bhasin, Chief of the Satellite Networks & Architectures Branch at NASA Lewis. Some of the key presentations were chaired and/or moderated by:

- Frank Gargione, ACTS Project Manager, Lockheed Martin
  "Internet over Satellite Networks"

- Aaron Falk, Network Systems Engineer; TRW Space & Electronics
  "TCP over Satellite: Issues, Relevance, and Experience"

- Pete Vrotsos, Chief, Space Communications Office; NASA Lewis Research Center
  "NASA Interoperability Experiments Program"

- Burt Edelson, Director, Institute for Applied Space Research; George Washington University
  "Addressing Interoperability"

- Thomas Brackey, Chair, Telecommunications Industry Association, Satellite Communication Division
  "Next Step to Further the Goal of Interoperable Satellite Networks"

Satellite Networks 1998 was the first public offering which addressed the accomplishments of NASA Lewis Research Center's Space Communications Program. This workshop provided a forum to assess the current state-of-the-art satellite networks, identify key issues, and highlight the emerging trends in next-generation architectures, data protocol development, communication interoperability, and applications. This in depth exploration included numerous presentations on satellite systems, state-of-the-art research, development and applications, and future trends on various topics related to satellite networks were given by industry, academia, and the government.

More information about Satellite Networks 1998 can be obtained at:
http://ctd.lerc.nasa.gov/events/5610/Workshop.html

Conference proceedings are available in hard copy print and can be obtained by contacting Dr. Kul Bhasin at:
Kul.B.Bhasin@lerc.nasa.gov

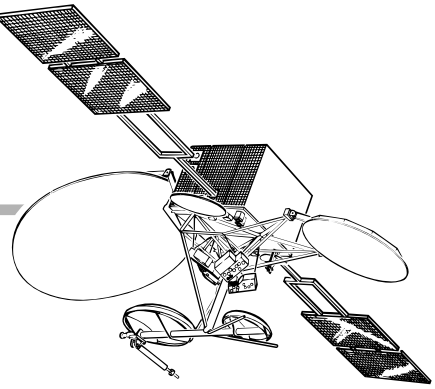
Coming in the Fall issue...

SCP technical publication list

...for your professional reference

Advanced
Communications
Technology
Satellite

Quarterly...Update



The Advanced Communications Technology Satellite (ACTS), launched in September 1993, is a vital element of NASA's Space Communications research and development program. Key technologies include antennas with high-powered electronically hopping multiple beams, onboard processing and switching, and Ka-band receivers and transmitters. The Satellite experiments period has been extended through 2000, allowing the capabilities of the ACTS system to continue to be made available to U.S. industry, government, and university experimenters. ACTS Project Manager Robert Bauer can be contacted at: (216) 433–3431 or Robert.A.Bauer@lerc.nasa.gov

The card below, which is being mailed to the many individuals, companies, customers, partners and others who have expressed interest in ACTS over the years, is spreading some BIG NEWS!!! ACTS, which has already achieved significant accolades and attention for its successful design, development, launch and operation, will continue to serve as an experimental platform through the year 2000. While ACTS remains a significant element of the project, our focus will be on demonstrating relevant communication technologies and applications that can work with ACTS to achieve our Space Communications Program vision of changing the way NASA and the Nation communicate through space.

In light of the tremendous contributions ACTS will continue to make to the Space Communications Program, the ACTS Quarterly is being retained as a feature in our Space Communications Technology Link newsletter. We will continue to provide a chronology of accomplishments, in particular for those readers who have followed the history and activities over the many years that this publication was in print. We hope you enjoy it!

LeRC Space Communications Program

Advanced Communications Technology Satellite (ACTS) Project Update

ACTS To Operate In Inclined Orbit Through 2000

NASA Lewis Research Center is inclined and ready for new research opportunities in:

- **Demonstrating NASA and other government use of future satellite services**
- **ATM, IP, and other protocols over satellites, including interoperability with terrestrial networks**
- **Evaluating satellite inclined orbit operations**
- **New Ka-band technology and hardware verification**

Details available now at http://acts.lerc.nasa.gov
Contact Mike Zernic, ACTS Experiments Manager at 216-433-5286
mzernic@lerc.nasa.gov

M-0432
Jul 98

ACTS Spacecraft Stationkeeping Maneuvers and the Inclined Orbit Control Mode

Alan Hewston, Control Systems Branch

The Advanced Communications Technology Satellite (ACTS) Inclined Orbit Control (IOC) mode, its (new) software, and accompanying ground operations were fully exercised during a 5-week, non-stop, in-orbit, functional test performed in Fall, 1997. During this test, the orbital inclination began at 0.09 degrees and grew to a maximum of 0.16 degrees before several North/South (N/S) Stationkeeping (S/K) maneuvers were made to bring the inclination back to zero. Typically a North/South Stationkeeping maneuver is performed every three to four weeks to reset the orbital inclination from 0.05 to 0.0 degrees. These maneuvers account for nearly all (96%) of the housekeeping propellant expenditure. Because the N/S maneuvers will not be done while in the IOC mode, the remaining propellant will last significantly longer for all other tasks. It has been estimated that a two month supply of N/S S/K propellant can be traded for the extension of the mission life as much as 2.5 years. The ACTS performance during the in-orbit test was acceptable and no problems were found that would prevent the spacecraft from operating in this mode full-time.

In the IOC mode, orbital inclination would grow at a rate of about 0.75 degrees per year. The ACTS ground trace will no longer remain fixed over the equator but instead will vary in longitude and latitude. The latitude (N/S) will vary as a sinusoid, with a magnitude equal to the inclination angle. The longitudinal (E/W) variation will be similar, but significantly smaller. Given the diurnally changing geometry, two system modifications are required to operate and continue successful experimentation during the ACTS IOC mode. First, the ACTS experiment terminals must be modified to continuously track the orbital motion. This design effort has been completed and the ACTS Earth terminals are being retrofitted to track to Spacecraft. Second, the spacecraft attitude control loop software must be modified so that the antenna panel is continuously pointed to lock on to the Cleveland beacon. This task has been flight tested in the above mentioned in-orbit IOC test.

The IOC flight software augmentation requires an automatic stepping of the momentum wheel pivot throughout the day. The steps are in phase with the orbital motion (above and below the equator), and their magnitude is scaled with the inclination angle. A stepping data table is generated on the ground, verified, and then uploaded to the spacecraft on a regular basis. Although this data load is unique to the IOC, the additional operations required are routine and not unlike other ACTS table loads. The stepping of the momentum wheel pivot angle results in an angular momentum transfer that keeps the spacecraft roll axis aligned with the orbital flight path, and the spacecraft pitch axis aligned with the orbit normal. This effectively maintains the same spacecraft-to-Cleveland geometry throughout the orbit. Because this momentum transfer affects all three spacecraft axes, additional IOC software is also needed to adjust the yaw attitude determination process. Prior to the IOC, the yaw attitude determination assumed that only the pitch axis rotates throughout the day. Now, this data must be generated both more frequently and to account for the daily as well as the seasonal variations of the Sun vector. Overall, the IOC requires additional routine operations and monitoring of the spacecraft, but no more than other spacecraft operating in an inclined orbit. All new IOC software, table loads, and operations have been thoroughly tested within the spacecraft attitude system processor.

(This article is a follow-on to “ACTS Spacecraft Stationkeeping Maneuvers” published in ACTS Quarterly Volume 2, June 1997.) For a copy of this article contact:
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Higher and Higher: A Reflection of the ACTS High Data Rate Experiments Program

Michael J. Zernic, ACTS Experiments Office, NASA Lewis Research Center

The Advanced Communications Technology Satellite (ACTS) High Data Rate (HDR) Experiments program,

which combined truly unique ground and space capabilities with innovative applications, has exceeded expectations. Besides proving that satellite communications can be achieved at comparable speed and performance as fiber networks, the respective interoperability issues and promising applications have been dispelling conventional “can’t be done” myths.

The NASA ACTS has the bandwidth and the routing capability to provide wideband networking. This is referred to as the Gigabit Satellite Network (GSN) and is comprised of several HDR ground stations in conjunction with the spacecraft’s capability. The GSN was designed to provide fiber-like service by incorporating Reed-Solomon coding and offset-QPSK modulation to achieve 622 Mbps channels with bit error rates in the range of 10 to12. This is comparable to terrestrial OC-12 fiber service. The ground stations were designed with SONET interfaces and the flexibility to utilize either one 622 Mbps or a combination of 155 Mbps channels. Further, by using electronically hopped spot beams and an on-board microwave switch matrix, true satellite-switched time division multiple access is achieved. The Defense Advanced Research Projects Agency (DARPA) partnered with NASA on the design, development, and operation of the GSN.

This capability enabled a unique and advanced experiments program to examine the feasibility of wideband satellite communications, respective protocol performance over wideband hybrid networks, and several interesting applications. The strategy of the HDR experiments program was to start simply and become increasingly complex in networking scenarios and technical objectives. After an intense GSN integration and test, the first such field experiment commenced in February 1995 and involved linking a workstation at the Boeing Commercial Airplane Group in Seattle, Washington with a Cray Supercomputer at NASA Lewis Research Center (Lewis) in Cleveland, Ohio. The application involved Boeing engineers conducting a “numeric wind tunnel” test of an engine inlet in real time from a remote facility—a revolution in conventional simulation testing. A protocol stack of modified TCP, IP, and ATM was used over the SONET network primarily comprised of the ACTS link. Data rates between 58 and 120 Mbps were achieved over the 155 Mbps channel, although the window size of the workstation was a limitation.

An experiment involving the National Center for Atmospheric Research in Boulder, Colorado and the Ohio Supercomputing Center in Columbus, Ohio followed close behind, which linked their respective supercomputers together over a 155 Mbps ACTS channel. The application was a real time and interactive modeling of Great Lakes weather conditions using a hydrodynamic numeric model on one machine and an atmospheric model on the other. HiPPI was included in the protocol stack of TCP, IP, and ATM over the SONET network. Because the Cray supercomputers permitted symmetric large window sizes, sustained throughputs of 120 Mbps were achieved. This experiment was involved with one of the first public demonstrations of the GSN at the ACTS Results Conference in Cleveland, OH in September of 1995.

Since these trailblazing experiments validated the feasibility of wideband satellite communications, many combinations of ACTS and fiber terrestrial networks have been initiated involving a variety of investigations. These included advancing applications which take advantage of the capability and agility that this type of satellite system technology offers. Such applications dealt with telemedicine as Mayo Clinic in Rochester, Minnesota conducted multiple, simultaneous digital cardiology applications with several medical institutions in Phoenix, Arizona; remote science as the Jet Propulsion Laboratory (JPL) in Pasadena, California remotely controlled the Keck Observatory on the big island of Hawaii allowing astronomical images to be computer enhanced and interpreted in real time at a more robust facility by a broader group of specialists; high definition video post-production distribution as Sony Studios in Culver City, California linked their respective studios in Japan over the “tribrid” combination of Ka-Band ACTS representing the next generation of satellite systems with Ku-Band Intelsat and fiber representing current means; virtual reality of California and even Mars terrain using Terravision as the means to remotely retrieve various parts of the data set from geographically dispersed servers in seamless fashion; and various interactive seismic data acquisition and oil exploration scenarios as precursors to a true mobile demonstration.

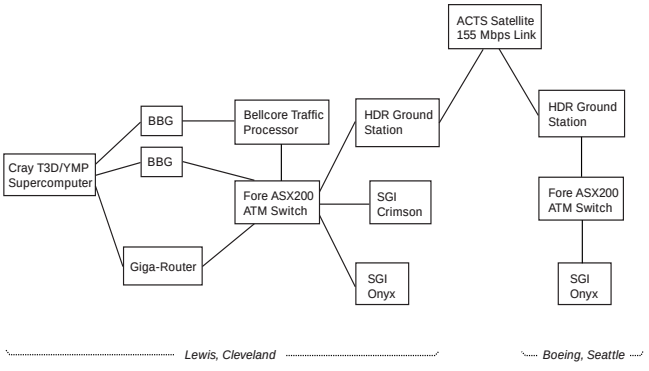
Further, in accord with the overall experiments program strategy, the HDR ground stations have been

relocated several times and have eventually settled in locations with prime access to terrestrial fiber testbeds such as the NASA Research & Education Network (NREN), Advanced Technology Demonstration Network (ATDnet), Multimedia Applications and Gigabit Internetwork Consortium (MAGIC), and the National Transparent Optical Network (NTON).

The GSN is currently configured to easily conduct hybrid interoperability issues at 622 Mbps. The first ever true end-to-end test of this nature was initiated in February 1997. The test configuration used over $1M worth of donated state-of-the-art vendor equipment—some items were not yet commercially available—set up at NASA Lewis and JPL. Three scenarios were investigated: a 622 Mbps duplex communications satellite model; a 622/1.5 Mbps asymmetric relay satellite model; and a 622/155 Mbps global broadcast satellite model which used an asymmetric hybrid satellite/terrestrial network of ACTS and NREN between the two sites. The main test objectives were to demonstrate the scalability of TCP/IP and optimization limits; demonstrate multi-service ATM implementation; establish a statistical relationship between buffer size, TCP/IP window size, and PDU length; and determine the effect of encryption and firewall devices on data throughput. The best sustained ACTS transfer was 220 Mbps and the best peak ACTS transfer was 350 Mbps over the 622 Mbps network, of which buffer overflow was determined to be the limiting factor.

Satellite Delivery of Wideband Services by ACTS

NASA Lewis Research Center, Cleveland, Ohio USA



Spring 1995

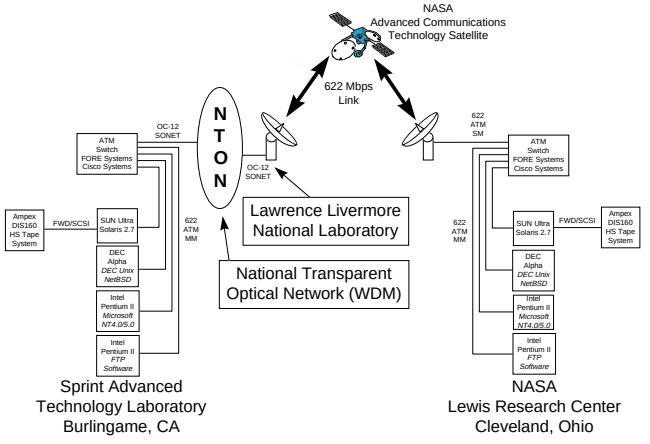
Numeric Wind Tunnel Test using a Cray and workstation, Spring 1995.

The next phase of OC-12 testing concluded with a demonstration at Supercomputing 97 in San Jose, California in November 1997. The intent was to demonstrate the feasibility of exchanging a Terabyte of application data between the show floor in San Jose and Cleveland in under five hours using the ACTS as a primary component in a 622 Mbps ATM network. Ampex tape drives and robots were the source of the terabyte of application data and several Sun Ultra workstations were used to optimize TCP and ATM system parameters in conjunction with the new Sun Solaris 2.6 operating system. Simultaneous tape-to-tape transfer using three pairs of workstations and tape drives reached an average, per stream, transfer rate of 120 Mbps; a single stream memory-to-memory transfer of 487 Mbps between a Sun Ultra workstation in San Jose and one in Cleveland. A peak transfer rate of 96 percent of the theoretical rate was obtained in this investigation thereby dispelling any myths about using TCP/IP over geosynchronous satellites for wideband applications.

The next round of 622 Mbps testing has begun in May 1998 and is building upon past experience to catalyze a cross-industry partnership promoting non-biased technology transfer in the area of hybrid communication interoperability. The primary objective is to optimize point-to-point data transfer over ACTS using TCP/IP off-the-shelf implementations across multiple

118x End-to-End Network Layout

NASA Lewis Research Center, Cleveland, Ohio USA



Spring 1998

Multi-Platform, High Speed Geo-protocol Performance Test using a variety of workstations and ATM equipment, Summer 1998.

computer platforms and operating systems such as Sun, DEC, Intel, and Microsoft set in a telecommunications infrastructure comprised of Sprint, Fore Systems, Cisco Systems, and Ampex Data Systems. Furthermore, satellite systems companies Lockheed Martin, Hughes Space Communications, Spectrum Astro, and Space Systems/Loral are involved to address first hand lingering questions that exist about the ability/validity of TCP/IP and ATM to deliver advanced services over Geostationary platforms.

The success of the HDR experiments program has not only stimulated advanced applications and network concepts, but has also tested and implemented two key TCP/IP performance enhancements authored by the Internet Engineering Task Force (IETF). Specifically, those enhancements are RFC 1323 TCP Extended Windows and RFC 2018 TCP Selective Acknowledgement.

For more information, you may contact the author at: Michael.J.Zernic@lerc.nasa.gov

TCP/IP Over ATM Interactions

Research into High Data Rate/High Delay Environments

Daniel Shell, CISCO Systems Engineer Federal Division

The Research Team:

Dan Glover	NASA SAA Technical Manager
Dan Shell	CISCO SAA Technical Manager
Will Ivancic	Technical Coordination
Doug Hoder	ACTS HDR Coordinator
Dave Pleva	SAA Network Engineer
Greg Kubat	LANE PI
Tom vonDeak	PNNI PI
Mark Allman	RED PI
Cindy Tran	TCP Over ABR PI
Jim Griner	High Speed TCP PI
Paul Mallasch	DICOM PI
Bob Dimond	Network Engineering Support

NASA Lewis signed a cooperative agreement (SAA3-131) with CISCO on October 16, 1997 to conduct Internet experiments over satellite channels. NASA is supplying the testbed including an ACTS satellite channel, CISCO is providing networking hardware for the duration of the experiments. The experiment was approved by ACTS management and is known as Experiment 138, “ATM and TCP/IP Interactions.”.

The tests will make use various experimental networking testbeds at Lewis Research Center, including the Satellite Networks and Architectures Branch’s Internet Protocols Testbed. The testbeds consist of UNIX computers, routers, switches, modems, satellite channel emulators and connections to the ACTS satellite and a Ku-Band terminal which is under construction . The testbeds are part of a NASA’s research program started at the behest of the satellite communications industry to optimizing current communication protocols in providing Internet connectivity over satellites. Research results arising from this agreement will be made public and are to the benefit of NASA, the commercial satellite industry, and the networking industry.

The Research Plan

ATM is maturing as a wide area network technology. ATM with TCP/IP as a network protocol is very common in current wide area network implementations. Our research will study the behavior of TCP/IP, ATM Switched Virtual Circuits (SVC), Private Network to

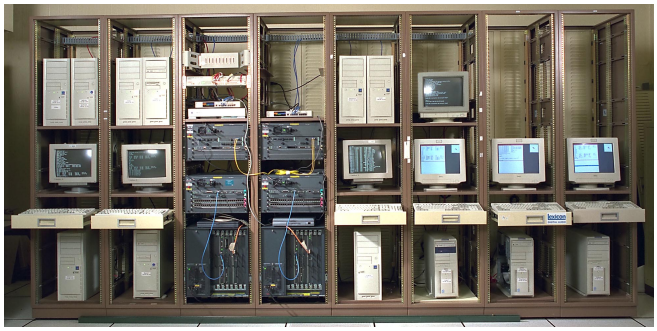
Internet Protocol Research Team—Back row: Bill Hart, Paul Mallasch, Tom vonDeak, Alan Richard, Dan Shell; Middle row: Dave Beering, Bob Dimond, Jim McKim, Brian Frantz, Jim Griner, Mark Allman; Front row: Joe Ishac, Will Ivancic, David Brooks, Cindy Tran, Shannon Steinfadt. Not pictured: Dan Glover, Greg Kubat, Doug Hoder, Dave Pleva, Ernest Rho.

Network Interface (PNNI), and Available Bit Rate (ABR) with it's various congestion controls in a high delay, high data rate environment. The data rates will be OC-3 (155 megabits per second) and OC-12 (622 megabits per second).

Along with the Switched Virtual Circuits (SVC), we will be studying Request for Comment (RFC) 1577 and Local Area Network Emulation (LANE) 1.0 behavior in this environment. One of the applications we will be using for this research is DICOM. DICOM is a telemedicine standard. We chose DICOM because the file sizes are long enough to fill the high data circuits and DICOM uses TCP/IP as its transport protocol.

The DICOM 3.0 standard has been developed by the American College of Radiology and the National Electronics Manufacturers Association to enable the communication and transmission of images and other medical information from and between various medical sources and users (computer workstations, MR imagers, film digitizers, archives). Since data transmission using DICOM depends upon the TCP/IP protocol, problems with TCP/IP and satellite links will affect DICOM performance, particularly in cases where DICOM database queries require multiple question and answer transmissions between the database and the requester. Hence, testing of DICOM performance over satellite, and development of performance improvements, must be addressed in future research.

The following equipment has been added to the Lewis testbed for this effort: two Catalyst 5000 Ethernet switches with OC-3 (155 Mbps) LANE modules, two 7507 routers with large buffer modules, OC-3 ATM modules, Fast Ethernet, three LS1010 ATM switches with PNNI routing, OC-3 and OC-12 (622 Mbps) ATM modules.



Internet protocol testbed (7/16/98).

We expect to find that LANE, Classical IP and PNNI will perform over a high data rate, high delay network, but that some parameters may need to be adjusted and possibly some new standards will need to be written to achieve maximum network performance.

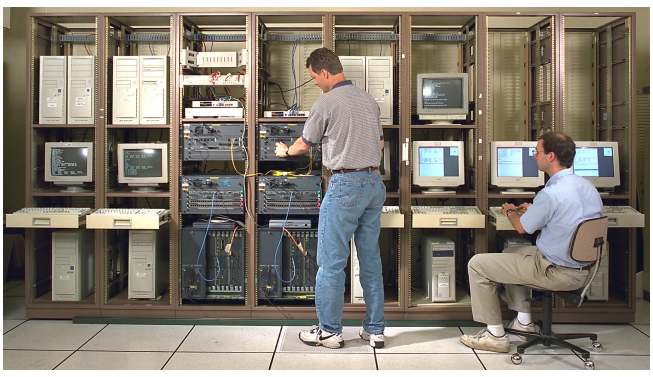
Research Into Quality of Service Over High Delay, High Data Rate Networks

Our research will study Resource Reservation Protocol (RSVP) to define various network parameters using the 7507 routers and DICOM as the test application. Random Early Detection will be studied to see how this congestion control mechanism behave in a Satellite network.

We will research Classical IP and LANE using ABR (Available Bit Rate) congestion control mechanisms and Quality of Service (QoS) parameters with DICOM and the high delay network.

ATM Cell Routing in a Satellite Network (PNNI)

Private Network to Network Interface (PNNI) is an ATM Forum standard for cell route calculation. PNNI is a link state routing protocol like Open Shortest Path First (OSPF). This protocol not only routes cells around failures but will also determine the best path, least congested and other factors in determining how the ATM traffic should flow. PNNI is a multilayer network. For instance, Routing Information Protocol (RIP) routing is only one layer and OSPF is a two-layer network. Also PNNI allows for a large number of network layers called peer groups. This feature allows for large scale ATM network deployments. Our research will be studying PNNI phase 1.

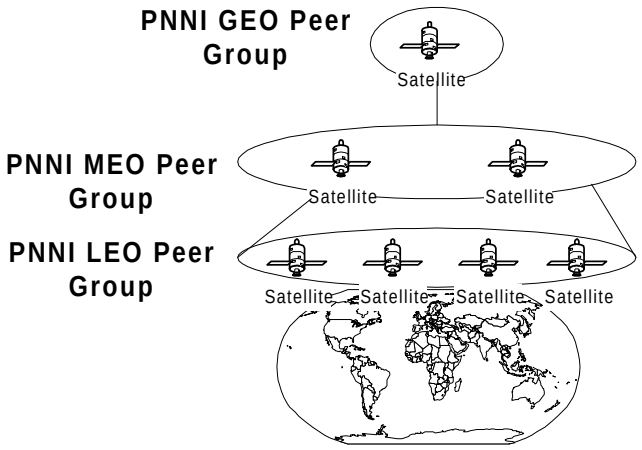


Gathering data are (left) Mike Howard,System Administrator; and Jim Griner, Research Engineer (7/16/98).

Using PNNI in LEO, MEO, GEO Satellite Networks

Lately, there has been a lot of attention given to the design of Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and Geosynchronous Earth Orbit (GEO) satellite networks. PNNI could be used to take advantage of the different characteristics associated with three orbital planes. By using PNNI, an ATM Network could be set up to use the Terrestrial network as a peer group, the LEO Satellites as a separate peer group, MEO as another peer group and finally the GEO as yet another peer group. It would be possible to route traffic during call setup over these satellites to the various destinations based on weighting parameters assigned to routing paths. For example, traffic from Cleveland to Columbus might take the LEO route, traffic from Cleveland to San Francisco would take the MEO route, and finally, traffic from Cleveland to Tokyo takes the GEO route.

Example:



Conclusion:

We expect our research to advance networking knowledge of how TCP/IP and ATM switched circuits operate on high data rate and high delay networks. By using the DICOM telemedicine application for our test we expect to gain experience with this application over a satellite network.

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Satellite Telemammography Network Experiment at RSNA '97

Robert Kerczewski and Paul Mallasch, Satellite Networks and Architectures Branch; Brian Kachmar, Analex Corporation, NASA Lewis Research Center

The Satellite Telemammography Network (STN) Team at NASA Lewis Research Center (LeRC) was invited to exhibit in the *Info*RAD area at the Radiological Society of North America (RSNA) Annual Meeting and Scientific Assembly in Chicago, Illinois held November 30 - December 5, 1997. *Info*RAD emphasizes practical applications utilizing advanced technologies and allows RSNA attendees to earn Continuing Education Units (CEUs) by participating in the demonstrations offered.

At RSNA '97, the STN team exhibited a telemammography workstation and two high-resolution ***Mega****Scan* monitors. This display showed the method for displaying digital mammography images for viewing by radiologists, as well as demonstrating the quality of satellite transmitted, lossy-compressed images. The display also featured a continuously running five-minute video on the Satellite Telemammography experiment and its relationship to the ACTS Program. Several posters were developed and displayed to give onlookers general information; a one-page brochure with additional information and contacts was distributed.

The exhibit was staffed by Robert Kerczewski, Paul Mallasch, and Brian Kachmar of NASA LeRC; and Dr. Kimberly Powell, Mary Barry, R.N., and Stefan Ganobcik of the Cleveland Clinic Foundation (CCF) who demonstrated the digital mammography displays, responded to questions, and held discussions with more than 260 interested people. These people included radiologists, hospital administrators, telemedicine experts, and image compression specialists, as well as many others from radiology and mammography disciplines.

It was a highly successful exhibit and served as an excellent medium to inform others in the medical community about the advances that have been made by the STN Project, as well as gaining significant new information from the radiology community. Many

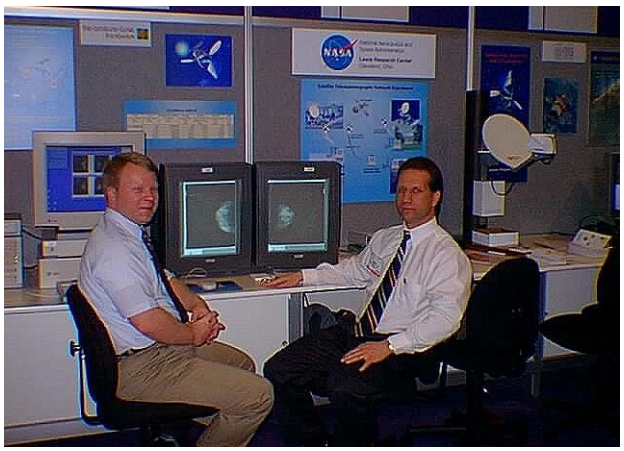

Figure 1.—(From left to right) Stephan Ganobcik of the Cleveland Clinic and Brian Kachmar of Analex at the RSNA '97 Exhibit at McCormick Place in Chicago, Illinois.

possible future collaborations and/or technology transfers were discussed. These will be assessed as more information and indication of real interest become available.

Satellite Telemammography Network Experiment Status

To date, the team has transmitted more than 1400 digitized mammograms over ACTS and have yet to encounter a single satellite-link-induced error. Included in these 1400 images were 60 cases (240 images) of pathologically proven images. These images have allowed the Cleveland Clinic to complete a clinical study comparing film-based mammography cases to digitized film cases scanned at 100 micron resolution. The study found that the diagnostic results were equivalent for the digitized film images as compared to the original film, and in fact two of the readers in the study actually performed slightly better when viewing the cases digitally on the high-resolution ***Mega****Scan* monitors.

A second study at the Cleveland Clinic is in progress documenting the diagnostic accuracy of the satellite transmitted, 8 to 1 compressed images. The study is expected to be completed within the next month.

The University of Virginia is planning on contributing some direct digital images for use in the STN experiment. This is very important, because direct digital imaging (as opposed to digitized film) is expected to gradually replace film-based mammography. The file size for direct digital images is significantly greater and therefore would be an ideal candidate for compression and subsequent transmission via satellite.

Satellite Telemammography Network Experiment Plans

The immediate goals for the STN are as follows: 1) completion of the transmission of the 100 micron digitized film images, 2) compression and transmission of 50 micron digitized film images, 3) compression and transmission of direct digital images, and 4) complete the associated clinical studies for all three. Also, additional "simulated satellite telemammography" sessions are planned. This is a session in which a case (4 images) is compressed, transmitted, received, and de-compressed, and then immediately reviewed by a radiologist for primary diagnosis.

A Phase II for the STN Experiment is in the planning stages. Initial plans call for placing a Very-Small-Aperture-Terminal (VSAT) at a Cleveland Clinic site in Bucyrus or Ashtabula, Ohio. Actual patients would participate in a satellite telemammography test which would encompass everything from the exam to the satellite transmission to the review by a radiologist at the Cleveland Clinic Main Campus. This would all be accomplished in a time frame that would allow for discussion of the results with the patient and additional images to be taken, if necessary.

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Live From the Rainforest

Adesh Singhal, Project Manager for "Live From the Rainforest"

The ACTS Project supported an activity called "Live From the Rainforest" which was a live interactive video show sponsored by PBS, NSF, and NASA. It followed in a series of "Live From ..." shows. The "Live From….." series of documentary programs on the public broadcast service have brought real life science endeavors home to the viewing public. Previous broadcasts have included "Live From the Stratosphere", seen in part from the NASA Kuiper Airborne

Observatory via ACTS, “Live From Antarctica 1”, broadcast in part from McMurdo Station and the south pole, and “Live From Antarctica 2” from the deck of the R/V Polar Duke and Palmer Station. As part of the Passport to Knowledge program, each broadcast was accompanied by a wide range of teaching materials which also included interactive forums such as EMAIL and Live Audio Feedback to the researchers and electronically available researcher’s logs. The purpose of this whole package was to allow the student audience to experience what it might be like to actually be there with the scientists in their work. Passport to Knowledge uses broadcast TV, videotape, email, the world wide web, and hands on discovery activities so students can actively simulate the science seen on camera and on-line in their own classrooms.

ACTS supported two of the previous shows, Live From the Stratosphere, Live From Antarctica-2, with JPL’s mobile terminal equipment was used, but this is the first time NASA Lewis took a lead role in providing the Ground Station link. Lewis led the effort to provide the live video link from a field research site in the Amazon over ACTS and terrestrially linking it to Mississippi State University where the interactive segments were produced into a show for middle school aged students as a PBS program. The students were able to interact live with the scientists during three live shows.

Lewis’ role in this activity was to supply the primary communications links between the Rainforest film crew and main PBS production site in the United States. These links included both the live video broadcast from Rainforest and return audio link from the participating classrooms, as well as supplementary audio, Fax, and Internet connections.

(From left to right): John Diamond and Greg Kubat transporting ACTS TIVSAT hardware from the boat to the Ariau Jungle Tower on March 19, 1998.

1.2 Meter TIVSAT antenna outdoor setup on Ariau Tower helicopter pad on March 19, 1998.

This project provided ACTS an opportunity to demonstrate Ka Band communications using ACTS’s T1VSAT earth station in the near 100% relative humidity and hot environment. ACTS communications links have never been tested in such a harsh environment before. Lewis’ involvement in this activity also supported NASA’s mission to provide and enhance the scientific educational programs for school children across America. This also provided the Public Broadcasting Services viewing public an opportunity to learn about NASA’s Advanced Communications Technology Satellite and its communications technology using the Ka Band and how it can be used for long distance learning. The objective of this activity was to demonstrate the utility and performance of the ACTS T1VSAT earth station and ACTS system for the following functions:

1. to provide live video feeds from Rainforest for three live PBS broadcasts

2. to produce non- real time video feeds from Rainforest for the purpose of providing background footage to the Live From Rainforest producers before the live broadcasts (continuous through Mar-Apr terminal deployment)

3. to provide voice communications to and from Rainforest for production purposes as well as to provide interactive communications between the Rainforest researchers and students and faculty back in the United States

4. characterize the effect of Tropical Rain events on T1VSAT earth station operation and performance

In completing the objectives of this experiment, the LFRF activity exercised several of the ACTS

communications technologies, including the use of Ka Band, the use of steerable and fixed spot beams bandwith on demand and base band processing on the satellite.

There were three main components of the LFRF communications service. The three parts were the United States Communications hub, the Rainforest communications terminal and the Advanced Communications Technology Satellite system. Figure 1 shows the overall architecture of the LFRF communications service.

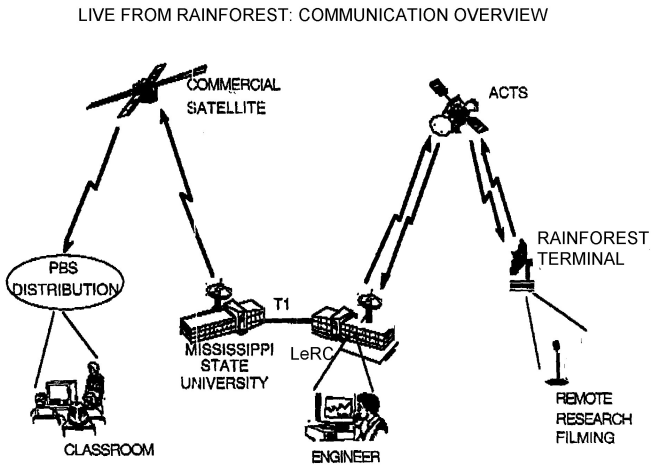

Figure 1

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Beyond the Rainforests of Brazil and "Live to Cleveland"

Jennifer J. Sibits, ADF Corporation, Public Relations

Producers of "Live From the Rainforest" extended NASA an invitation to present the wonders of the Amazon Rainforest to local Cleveland students in a program which featured an "electronic field trip" to Brazil." The field trip was a live broadcast of an interactive science and education program that enabled students of Robert H. Jamison CompuTech Center to engage in a distance-education program organized by the Education Department of the Cleveland Metroparks Zoo.

Lewis engineers worked with the technical staff at the Metroparks to install a T1VSAT at the Zoo and ran a series of tests to validate satellite link performance. Given a big thumbs up, the show was a go. Students talked with scientist Rita Mesquita who answered questions about plant and animal life and laughed as a local businesswoman named Elaine, playfully demonstrated how to communicate with other locals, namely the ever so friendly and domestic like monkeys.

The rainforest of Brazil is just one of many places on earth that many of us, like the Cleveland students, may never get to actually visit. With the advancing capabilities of communication satellites and programs like Passport to Knowledge, an "electronic field trip" may be just the ticket we need.

Many thanks to Passport to Knowledge, the producers and broadcast crew of "Live from the Rainforest" Rita Mesquita, Elaine and the ACTS Project for bringing the Rainforests of Brazil to the Cleveland students.

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Visit Passport to Knowledge "Live From the Rainforest" at:
http://passport.ivv.nasa.gov/rainforest/intro.html

Adesh Singhal, Lewis project manager for "Live From the Rainforest" and Christine Khornak, Education Specialist for the Cleveland Metroparks Zoo, teach students from Robert H. Jamison CompuTech Center about satellite technology.

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